

Comparative Assessment of Canal Transportation, Dentin Loss, and Remaining Root Filling Material by Different Retreatment Files – An *In vitro* Cross-Sectional Study

Abstract

Aim: The purpose of this study was to evaluate the centering ability, canal transportation and efficacy of re-treatment rotary and hand files in removing Gutta Percha from root canals using Cone Beam Computed Tomography (CBCT). **Materials and Methods:** Sixty extracted human maxillary anteriors were obturated and randomly divided into three groups. Root fillings were removed with ProTaper Universal retreatment system, R-Endo system, and Hedstrom files. CBCT scans were taken. **Statistical Analysis and Results:** The data were analyzed using the Statistical Package for the Social Sciences (SPSS 15.0, IBM). The mean and standard deviation among the groups was calculated by one-way analysis of variance, Kruskal–Wallis, and Mann–Whitney U-tests, and the comparison among the various groups was done by post hoc Tukey's test. A statistically significant amount of remaining root canal filling material and canal transportation was noted ($P < 0.05$). **Conclusion:** No system completely removed the root filling material from root canals. Manual instrumentation resulted in more dentin loss and canal transportation than rotary file system.

Keywords: Canal transportation, cone-beam computed tomography, nickel–titanium, ProTaper Universal retreatment files, R-Endo retreatment files

Introduction

Persistence of microorganisms within the root canal intricacies is usually the main reason for root canal treatment failure.^[1] Therefore, to reduce the number of microorganisms, the obturating material (gutta-percha and root canal sealer) must be removed as much as possible from the root canal system.^[2]

Obturating material removal from root canal system can be done by various methods such as ultrasonic technique, heat-carrying instruments, chemicals, endodontic hand files, and engine-driven rotary files.^[1,2] Removal of gutta-percha using hand files requires more time than the engine-driven rotary systems.^[1]

Advent of technology has led to introduction of newer file system, especially for retreatment such as ProTaper Universal retreatment (PTUR) file system (Dentsply Maillefer, Ballaigues, Switzerland) and R-Endo file system (Micro-Mega, Besancon, France).^[3] The ProTaper

Universal retreatment (PTUR) file system consists of D1 (size 30, 0.09 taper, active tip, length 16 mm), D2 (size 25, 0.08 taper, nonactive tip, length 18 mm), D3 (size 20, 0.07 taper, nonactive tip, length 22 mm) and two ProTaper finishing files (F4, F5).^[1,3] The R-Endo retreatment file system is comprised of Rm hand file (25, 0.04 taper); R_e (size 25, 0.12 taper); R₁, R₂, and R₃ (each 25 size and a respective taper of 0.08, 0.06, or 0.04); and an optional finishing file R_s (size 30, 0.04 taper). These files have nonactive tip, triangular cross section, no radial lands, and equally spaced cutting edges.^[4,5]

Information about removal of root fillings using retreatment files from curved canals are less, as most of the authors worked on their efficacy in straight root canals. Furthermore, the root filling removal and further instrumentation is challenging and difficult in curved root canals as compared to straight counterpart.^[3]

Canal transportation can be defined as any undesirable deviation from the natural canal

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path. The asymmetric material removal may displace the long axis of curved root canal during shaping and cleaning. Damage to apical foramen, zip formation, perforation, and ledging could be the possible outcomes of canal transportation.^[6]

There are various methods to evaluate the efficacy of different methods in removing root canal filling material from the canals. These include splitting the teeth longitudinally and visualizing them using a stereomicroscope or using Image Analyzer software, radiography, and digitized images.^[7] Loss of residue is usually encountered with splitting methods, thus providing inaccurate assessment.^[8] Radiographic images are two-dimensional (2D) representation of a 3D object and are subjected to distortion and magnification.^[9]

As evident from the various literature, there are numerous methods to remove root canal filling material and to evaluate the canal shape following retreatment procedure.^[10] Tasmedir *et al.* reported significantly less root canal filling material with PTUR as compared to R-Endo, Mtwo, and Hedstrom files. Complete elimination of root fillings was not noted in any of the groups.^[4] Gogulnath *et al.* reported no statistically significant difference for canal centering ability between PTUR and R-Endo groups.^[11]

Advances in imaging technology with the introduction of cone-beam computed tomography (CBCT) have led to appraisal of the structure three-dimensionally, thus allowing detailed evaluation of morphologic features without destroying the tooth sample.^[5] CBCT imaging is a noninvasive technique for analysis of canal geometry and efficiency of shaping techniques by superimposition of preinstrumentation and postinstrumentation images.^[12]

Literature search reported that the hand files showed more dentin loss and were less centered in the canals as compared to rotary file systems. Hence, null hypothesis was considered, and the study was designed to analyze the canal transportation, centering ability, and remaining root filling material by ProTaper Universal retreatment system (PTUR), R-Endo retreatment system, and hand files.

Materials and Methods

Permanent human maxillary lateral incisors extracted for periodontal reason with closed apices and a mean curvature of 20°–35° at the apical third as per Schneider's method were collected in 1-month duration. Teeth were radiographically assessed. The teeth with canal calcification, severe canal curvature, presence of additional canal, cracks/fractures, and internal and external resorption were excluded from the study. Teeth were visually inspected for fracture or cracks under surgical operating microscope (G4, Global Surgical Corporation, St. Louis, MO, USA). The sample size was calculated using the results of previous study by Tasmedir. Keeping a confidence interval of 95% and a power of at least 80%, the sample size of 20 per group was kept. Following

this, a total of sixty maxillary lateral incisors were selected. The soft-tissue residues and calcified materials were removed using scaler and were immersed in a 0.1% thymol solution for 24 h. The teeth were then rinsed under running water to eliminate thymol residues and stored in saline until use. The Institutional Ethical Committee approval was obtained, and the study was completed in 7 months.

Mounting of the samples

To reproduce the clinical situation, the instrumentation procedures were done under a surgical operating microscope (G4, Global Surgical Corporation), following fixing of samples with putty in a maxillary jaw model (ModuPro Endo, Acadental, Overland Park, KS, USA) on a phantom head.

Samples were decoronated to standardized root length of 16 mm and verified using digital caliper. A small groove was marked using HiDi 501 and 720 round diamond bur (Dentsply Ash, Weybridge, UK) at 3 (apical), 6 (middle), and 9 (coronal) mm from root apex, to facilitate the pre- and postinstrumentation CBCT image superimposition and analysis.

Root canal filling

The no. 10 k-file (Dentsply Maillefer, Ballaigues, Switzerland) was used to establish the canal patency. All the samples were prepared to the size A1 (size 40, 0.04 taper) Neoniti (Neolix, Châtres-la-Forêt, France) rotary file. The canals were irrigated during instrumentation procedure with 3% sodium hypochlorite (Novo Dental Products Pvt. Ltd, Mumbai, India) saline and 17% ethylenediaminetetraacetic acid (Largal Ultra, Septodont, Saint Maitre, France) throughout the shaping and cleaning procedure and dried with paper points (Kerr Corp., Romulus, MI) followed by obturation with the same size and taper gutta-percha with Cold lateral compaction. GuttaFlow was used as root canal sealer (Coltene/Whaledent, Langenau, Germany) in all the samples.

The teeth were temporized using Cavit G (3M ESPE, Germany) and stored at 37°C in 100% humidity for 1 week to allow complete sealing of the sealer. Teeth were radiographed in buccolingual and mesiodistal directions to assess the radiographic adequacy of root filling, using the following criteria: reaching the working length, uniform radiopacity, and no voids.

Cone-beam computed tomography scanning following endodontic treatment

The teeth were removed from the jaw and mounted in blocks made of polyvinyl siloxane putty wash (Speedex; Coltène/Whaledent AG, Altstätten, Switzerland) measuring 5 cm × 5 cm to the level of their cemento-enamel junction in a parallel fashion for further comparison. A small piece of an orthodontic wire was placed at the corner of silicon blocks to determine the direction of scanning.

Samples were then scanned using CBCT equipment ORTHOPHOS XG 3D SYSTEM (Sirona – The Dental Company) with the following parameters: 64 kVp, 8 Milli-A, and 900 projections within a full rotation. The volume range on the object/ Field of view (FOV) corresponds to a cylinder with a diameter of approximately 8 cm and a height of approximately 8 cm.

The temporary restorations were removed, and 1 drop of d-limonene (Nippon Shika Yakuhin Ltd., Tokyo, Japan) was used for 2 min to soften the gutta-percha and facilitate easier initial penetration of retreatment files.

Teeth were then randomly divided into three groups ($n = 20$).

Group I (Hedstrom file group)

The canals were re-instrumented with Hedstrom files (H file) (Dentsply Maillefer, Ballaigues, Switzerland) of size 40, 35, 30, 25, and 20 in a circumferential quarter-turn push-pull filing motion to remove gutta-percha and sealer until WL was achieved.

Group II (ProTaper Universal retreatment file group)

ProTaper Universal retreatment files (Dentsply Maillefer Ballaigues, Switzerland) were used as per manufacturer's instruction with endomotor. D1 (30 / 0.09) instrument was used for coronal third, D2 (25 / 0.08) for middle, while D3 (20 / 0.07) for apical third.

Group III (R-Endo retreatment file group)

R-Endo retreatment files (Micro-Mega, Besancon, France) were operated with a speed and torque-controlled electric motor (X-SMART Dentsply Maillefer) according to manufacturer's instructions. The R_m was used to create pilot hole, followed by R_1 to coronal third and R_2 to two-third the working length. The R_3 was used to full length of the canal.

In all the three groups, the additional finishing was done with X3 ProTaper Next rotary file (Dentsply Maillefer, Ballaigues, Switzerland). In all the groups upon withdrawal of each instrument, adherent debris was removed from the files and canals were irrigated with 3% sodium hypochlorite solution and final rinse with saline. Instruments were discarded after being used in five root canals. Retreatment was deemed complete when no debris of gutta-percha/sealer was visible with naked eyes on instruments surface after being removed from the canals.

It should be noted that initial shaping and cleaning was performed by one trained operator while the retreatment procedure was performed by another trained operator. All the operators were having 2 years of clinical experience.

Cone-beam computed tomography scanning following retreatment procedure

Specimens were scanned after removal of root canal filling material in each group using CBCT equipment

ORTHOPHOS XG 3D SYSTEM (Sirona – The Dental Company) with the same parameters as discussed before.

Cone-beam computed tomography image analysis

Both images (scanned images immediately after shaping and cleaning and those after root canal filling material removal) were analyzed for the amount of residual filling material, dentin loss, and degree of canal transportation.

Measurement of canal volume and surface area

The area of the root canal and residual filling material was recorded using the following equation.

$$\text{Area \% of remaining filling material} = \frac{\text{Area of remaining filling material}}{\text{Area of canal wall}} \times 100$$

Measurement of canal transportation

The canal transportation was assessed using the Gambill formula, which is as follows:^[13]

$$T = (M1 - M2) - (D1 - D2).$$

Here, M1 and M2 represent the shortest distance between the mesial edge of root to mesial edge of cleaned and shaped canal and that of mesial edge of root canal from where the root fillings were removed, respectively. Similarly, D1 and D2 represent the shortest distance between the distal edge of root to distal edge of cleaned and shaped canal and that of distal edge of root canal from where the root fillings were removed, respectively.

From the formula described above, the following interpretation can be made. The value of $T = 0$ represents no transportation, $T > 0$ represents T toward mesial, and $T < 0$ represents toward distal aspect of root canal. The same formula can also be applied on buccal (B) and palatal (P) root aspect, where M will change to B or P and D will represent P or B or vice versa.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (IBM SPSS Inc, Chicago, IL, USA). The P value was taken as significant when less than 0.05 ($P < 0.05$). The mean and standard deviation among the groups was calculated by one-way analysis of variance, Kruskal–Wallis, and Mann–Whitney U-tests, and the comparison among the various groups was done by *post hoc* Tukey's test.

Results

In the coronal third, a statistically significant difference was noted when H file was compared with R-Endo and PTUR [Table 1]. However, no statistically significant difference was observed between R-Endo and PTUR [Table 1 and Figure 1a-1]. Among all the thirds, maximum root canal filling material was observed in apical third, followed by middle and coronal third in all the groups.

Table 1: Comparison of remaining gutta-percha material expressed as mean±standard deviation

Group	n	Mean±SD			P
		Coronal	middle	apical	
H File	20	11.84±1.02	14.61±1.26	8.09±2.62	<0.05**
Protaper	20	6.70±0.60	11.04±1.37	20.73±2.75	>0.05*
REndo	20	5.40±1.34	11.80±2.12	23.48±2.28	>0.05*

* $P > 0.05$ derived from ANOVA considered nonsignificant,

** $P < 0.05$ derived from ANOVA considered significant.

At all the three levels, H file resulted in more dentin loss than R-Endo and PTUR ($P < 0.05$). R-Endo and PTUR were similar in terms of dentin loss ($P > 0.05$) [Table 2].

At 6 and 9 mm levels, there was no significant difference among the groups in terms of canal transportation in mesiodistal direction ($P > 0.05$) [Table 3].

At 3 mm level, H file resulted in more canal transportation than R-Endo ($P < 0.05$) in buccolingual and mesiodistal directions, although R-Endo and PTUR were similar in terms of canal transportation in buccolingual ($P > 0.05$) [Table 4].

At 6 mm level, R-Endo resulted in more transportation than PTUR ($P < 0.05$), although H-file and PTUR were similar in terms of canal transportation in buccolingual view ($P > 0.05$) [Figure 2a-i].

Discussion

In 1998, the American Association of Endodontists Glossary of Contemporary Terminology for Endodontics defined retreatment as a procedure to remove filling material from the pulp cavity and also to clean and shape the root canal system again.^[14]

Microorganisms may persist or recolonize after obturation in the root canal system secondary to coronal or apical leakage thereby leading to endodontic failure.^[15]

Root canal retreatment is often required when the primary endodontic management fails. Retreatment aims at substantial reduction or elimination of microorganisms from root canal system.^[16]

Retreating a tooth through orthograde approach is possible in most of the cases. Nonsurgical retreatment should always be attempted in failed primary endodontic treatment cases. Surgical retreatment should always be the last resort to save a tooth.^[17]

To simplify the standardization of the specimens, single-rooted teeth were used. Furthermore, the lateral incisors offer distally directed apical curvature and do offer challenges in removing root filling material. Hence, maxillary lateral incisors with apical curvature were selected in the present study. Decoronation of the samples was done to standardize the working length and to eliminate variables related to coronal interference during access preparations.^[1,7,8,16]

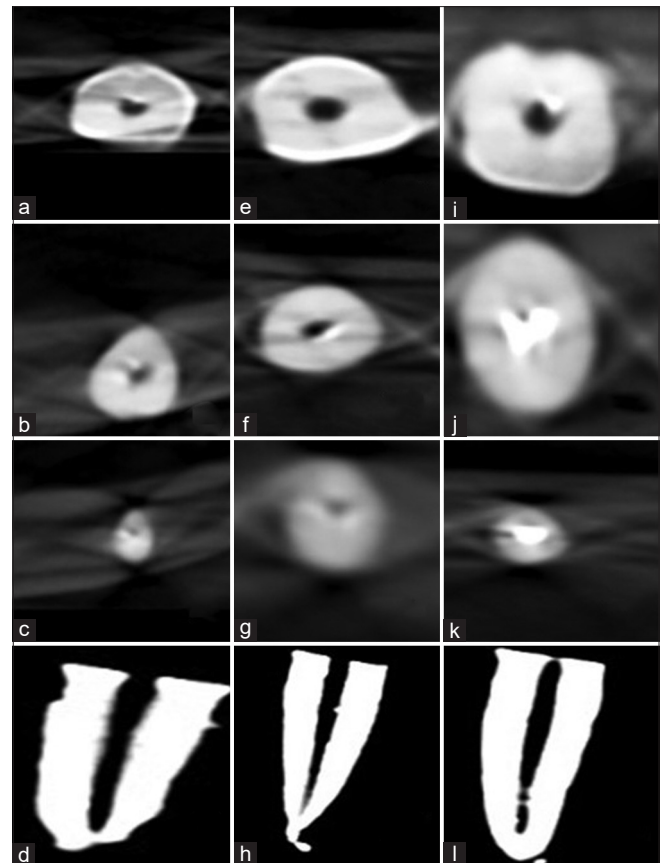


Figure 1: Three-dimensional reconstructed axial view of coronal (a, e, and i), middle (b, f, and j), and apical third (c, g, and k) of root canal and sagittal view of root canal showing remaining gutta-percha or sealer (d, h, and l)

There are various methods to remove the root canal filling material from the canals in the literature. This includes conventional hand files, Gates Glidden drills, ultrasonics, heat, laser, GPX drill, GG drill, and Endotec device contemporary nickel–titanium (NiTi) rotary files.^[5,18]

Using purely mechanical means for removal of root canal content can induce iatrogenic errors such as perforation, ledge, canal straightening, or alteration of canal anatomy [Figure 3]. Canal transportation is defined as any undesirable deviation from the natural canal path. In curved canals at the apical region, the outside (convex) canal wall may be overinstrumented, leading to unnecessary removal of healthy dentin. The infected dentin may remain at the inside (concave) canal wall. This can result in inadequate shaping and cleaning, probability of persistent apical lesions, strip perforations of the lateral root canal wall, and weakening of the root.^[6]

Removing filled content from canal with conventional H files is a laborious and time-consuming process. Rotary NiTi instrumentation may decrease operator and patient fatigue, thus completing the entire process with relative ease in less time.^[4,5]

A drop of GP solvent (d Limonene) plasticizes the gutta-percha at the canal orifice and facilitates easy penetration

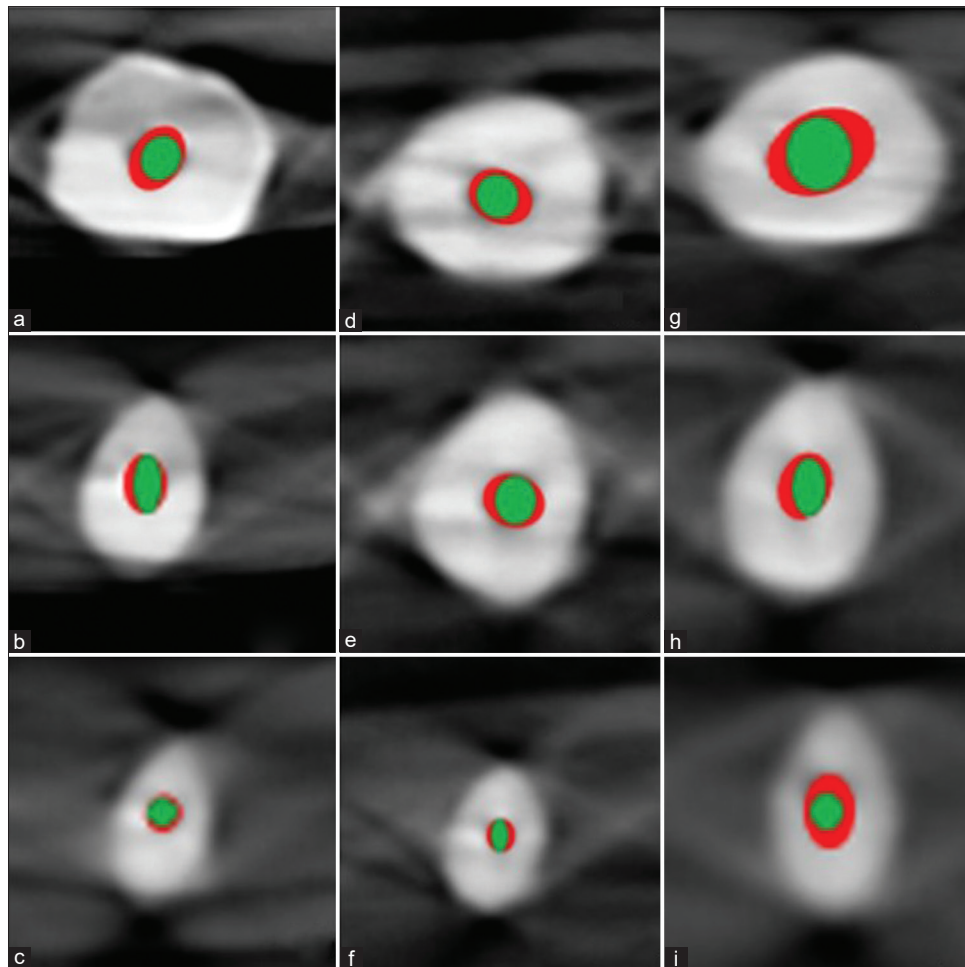


Figure 2: Three-dimensional reconstructed axial view showing canal transportation at coronal (a, d, and g), middle (b, e, and h), and apical (c, f, and i) third of root canals

Table 2: Comparison of the dentin loss in terms of mean±standard deviation at different levels among all the three groups

Group	n	Mean±SD		
		At 3 mm*	At 6 mm**	At 9 mm**
R-Endo	20	0.45±0.31 ^a	1.30±0.25 ^a	1.41±0.37 ^a
PTUR	20	0.55±0.42 ^a	1.38±0.38 ^a	1.42±0.55 ^a
H File	20	1.01±0.33 ^b	0.83±0.71 ^b	0.73±0.23 ^b

*Means one-way ANOVA and Tukey’s tests were performed, **Means Kruskal-Wallis and Mann-Whitney U-tests were performed. Different alphabets indicate significant difference in the same column. H file: Hedstrom files; ANOVA: Analysis of variance; PTUR: ProTaper Universal retreatment system; SD: Standard deviation

of retreatment files. Hence, GP solvent was used as an adjunct in removing filling material from canals.^[18]

Various techniques have been documented in the literature for evaluating the efficacy of root canal content removal with various aids including conventional radiography, clearing technique and digitized images, longitudinally splitting the tooth and visualizing it under operating microscope or stereomicroscope, obtaining images with camera, and

analyzing them using analyzer software.^[5] With splitting technique, inaccurate assessment may occur due to loss of residue.^[6] Radiographic images are 2D representations of 3D object and are also subject to magnification and distortion.^[8]

Advent of CT scan enabled 3D evaluation of entire root canal system. CBCT operates at a significantly lower effective radiation dose as compared to CT and also enables 3D evaluation. CBCT does not require destruction of tooth specimen and provides detailed visualization of morphologic characteristics including root canal systems.^[5]

Marfisi *et al.*, in their study, have mentioned that none of the experimental techniques guarantee complete removal of filling materials as previously reported. The CBCT evaluation found no significant difference between the instruments studied.^[5]

Gu *et al.* concluded that 10%–17% of canal area was covered with filling material in their study.^[11] Tasdemir *et al.* also reported the same.^[16] Tsesis *et al.* concluded that 10%–17% of canal wall was covered with filling material in their study.^[13] Unal reported 11%–27% of residual filling material, while Dall’Agnol *et al.* reported

Table 3: Comparison of the Canal transportation (M1-M2) - (D1-D2) in terms of mean±standard deviation at different levels among all the three groups

Group	n	Mean±SD		
		At 3 mm**	At 6 mm*	At 9 mm*
R-Endo	20	0.03±0.34 ^a	-0.12±0.39 ^a	0.008±0.15 ^a
PTUR	20	0.03±0.21 ^a	0.03±0.32 ^a	0.04±0.13 ^{ab}
H File	20	0.001±0.19 ^a	-0.06±0.30 ^a	0.24±0.23 ^b

*Means one-way ANOVA and Tukey’s tests were performed, **Means Kruskal-Wallis and Mann-Whitney U-tests were performed. Different alphabets indicate significant difference in the same column. H file: Hedstrom files; ANOVA: Analysis of variance; PTUR: ProTaper Universal retreatment system; SD: Standard deviation

Table 4: Comparison of the canal transportation (B1-B2) - (L1-L2) in terms of mean±standard deviation at different levels among all the three groups

Group	n	Mean±SD		
		At 3 mm*	At 6 mm**	At 9 mm**
R-Endo	20	0.31±0.23 ^a	0.53±0.33 ^a	0.02±0.48 ^a
PTUR	20	0.08±0.17 ^{ab}	0.05±0.21 ^b	0.01±0.122 ^a
H File	20	0.02±0.25 ^b	0.31±0.50 ^{ab}	0.26±0.51 ^a

*Means one-way ANOVA and Tukey’s tests were performed, **Means Kruskal-Wallis and Mann-Whitney U-tests were performed. Different alphabets indicate significant difference in the same column. H file: Hedstrom files; ANOVA: Analysis of variance; PTUR: ProTaper Universal retreatment system; SD: Standard deviation

62.21% of mean percentage of remaining filling material, while Takahashi reported 14.2%–27.9% residual filling material.^[3,19] The present study also stated that none of the groups showed complete removal of the root fillings. Hulsmann and Stotz reported that retreatment with Hedstrom file is more time-consuming than rotary instrumentation.^[20] The present study also reported reduced retreatment time with rotary NiTi files as compared to hand instrumentation.

There is statistically significant difference between Group 2 and Group 3 and Group 1 and Group 3, while there is no statistically significant difference between Group 1 and Group 2. This can be attributed to excessive taper and active tip of D1 of PTUR and larger pilot hole created by R_m [Table 1].

Aydin *et al.* concluded in their study that regardless of technique, more residual filling material was noted in the apical third than in coronal and middle third, as has been reported in the previous studies.^[21] While, contradictory results were noted by Zmener *et al.* in their study signifying less residual filling material in apical third, which may be attributed to decrease in buccolingual diameter of oval canals toward apices, thus allowing better contact of retreatment files with canal walls.^[22]

In the present study, GuttaFlow (Coltene/Whaledent, Altstatten, Switzerland) was used as a root canal sealer. It

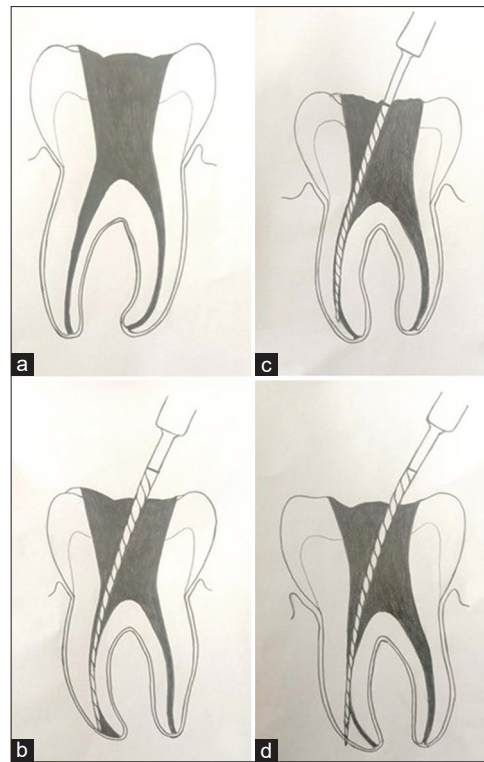


Figure 3: Schematic representation showing normal canal morphology (a), ledge formation (b), canal transportation (c) and perforation (d)

is a polydimethylsiloxane (C₂H₆O_{Si}) silicon-based sealer containing gutta-percha particles. The material is flowable, sets within 10 min, and exhibits slight setting expansion.^[23]

It seems that more homogeneous filling in the GuttaFlow group might have enabled the filling to be removed as a bulk filling.^[10]

At all the three levels, H file resulted in more dentin loss than R-Endo and PTUR ($P < 0.05$). R-Endo and PTUR were similar in terms of dentin loss ($P > 0.05$).

At 6 and 9 mm levels, there was no significant difference among the groups in terms of canal transportation in mesiodistal direction ($P > 0.05$) [Table 3].

However, at 6 mm level, R-Endo resulted in more transportation than PTUR ($P < 0.05$), although H-file and PTUR were similar in terms of canal transportation in buccolingual direction ($P > 0.05$) [Figure 2a-i]. This can be attributed to larger pilot hole created by R_m.

At 3 mm level, H file resulted in more canal transportation than R-Endo ($P < 0.05$) in buccolingual and mesiodistal directions, although R-Endo and PTUR were similar in terms of canal transportation in buccolingual ($P > 0.05$) [Table 4]. This can be attributed to aggressive nature and relatively least flexibility of H file.

A major contribution of this study was the use of CBCT as a method to assess the remnant root fillings, dentin

loss during biomechanical preparation and retreatment procedures, and canal transportation. CBCT is an emerging technology that allows for the evaluation of root canal anatomy, assessment of root canal morphology before and after instrumentation, measurement of 3D volume of filling material. CBCT allows for detailed visualization of morphological features without destruction of tooth.

However, the use of micro-CT would be more accurate and precise for the detailed evaluation of the root canal system. Decoronation was limitation of this study. The study would be of more clinical relevance if it would have been done on patients.

Clearly further studies are needed to assess the efficacy, maintenance of original canal morphology, and safety of NiTi rotary instruments during retreatment with complicated root canal anatomy.

Conclusion

Within the limitations of this *in vitro* study, the result showed that none of the systems completely removed the root filling. The overall dentin loss was highest when canals were instrumented with R-Endo, followed by PTUR and H files. In the R-Endo and H file group, higher canal transportation was observed in middle third while least in coronal third. CBCT proved to be a more reliable, noninvasive method and should be used in further studies for evaluating root canal filling material using newer instruments and techniques.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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